Energy, Mines and Resources Canada
Energie, Mines et Ressources Canada

CANMET
Canada Centre for Mineral and Energy Technology
Centre canadien de la technologie des minéraux et de l'énergie

PILLAR STRESS MEASUREMENTS AT DENISON MINE, ELLIOT LAKE, ONTARIO

B. ARJANG

ELLIOT LAKE LABORATORY

AUGUST 1986

This document is an interim report prepared for discussion and review purposes. It does not represent final conclusions and recommendations or the opinion of the Canada Centre for Mineral and Energy Technology (CANMET)

Ce document est un rapport préliminaire préparé et rédigé à des fins de discussion et d'examen. Il ne représente pas nécessairement les conclusions définitives de la direction du Centre canadien de la technologie des minéraux et de l'énergie (CANMET)

MICROMEDIA

MINERAL AND ENERGY TECHNOLOGY
MINING RESEARCH LABORATORIES
DIVISION REPORT M&ET/MRL 86-111(TR)

PILLAR STRESS MEASUREMENTS AT DENISON MINE, ELLIOT LAKE, ONTARIO

by

B. Arjang*

Cooperative mining stress measurements were completed at Denison Mine, Elliot Lake, Ontario. At five measuring sites, pillar stresses were determined using four-gauge CSIR biaxial strain cells.

The pillar stress determinations show that, in most cases, the maximum stress transfer occurs normal to the orebody. The magnitudes of maximum stress were 28.0 to 47.0 MPa, and minimum stress was in the range of 4.0 to 22.0 MPa. The overall stress field obtained is consistent with the pillar geometry and the distribution of mine openings.

Good agreement exists between average measured and estimated pillar stresses.

Keywords: Pillar stress determinations; Biaxial strain cell; Stress tensor.

*Research Scientist, Elliot Lake Laboratory, CANMET, Energy, Mines and Resources Canada, Elliot Lake, Ontario.

MESURES DE LA CONTRAINTE DANS LES PILIERS À LA MINE DENISON, À ELLIOT LAKE EN ONTARIO

PAR

B. Arjang*

On a effectué des mesures de la contrainte dans le cadre de travaux d'exploitation minière coopérative à la Mine Denison, à Elliot Lake en Ontario. Ces mesures ont été relevées dans cinq sites afin de déterminer les contraintes dans les piliers, à l'aide de quatre cellules de déformation biaxiales CSIR.

Les mesures de la contrainte dans les piliers indiquent, dans la plupart des cas, que le transfert maximum de la contrainte se produit normalement dans le gisement. Les contraintes maximales mesurées étaient de 28,0 à 47,0 MPa et les contraintes minimales étaient dans l'intervalle de 4,0 à 22,0 MPa. Le champs de contrainte total que l'on a obtenu, est compatible avec la forme géométrique des piliers et la distribution des ouvertures de la mine.

On a remarqué, de plus, qu'il y a conformité de la moyenne des données des contraintes mesurées avec les données estimées des contraintes dans les piliers.

Mots-clés: Mesures de la contrainte dans les piliers; cellule de déformation biaxiale; tenseur de tension.

*Chercheur scientifique, Laboratoire d'Elliot Lake, CANMET, Énergie, Mines et Ressources Canada, Elliot Lake, Ontario.

INTRODUCTION

Denison Mine is a room-and-pillr mine in the Elliot Lake mining camp in Northern Ontario. A 3-6 m thick uranium-bearing conglomerate reef dips at 20°. Mining the same reef, but up-dip of the Denison Mine, is the Rio Algom's Quirke Mine. The two mines are separated by a 12 m wide boundary pillar.

The rockburst prone area of the boundary pillar and the complex room-and-pillar geometry has been the subject of particular scrutiny. Regional model studies, numerical modelling and stability evaluation for the Denison/Quirke boundary pillar have been conducted (1,2). In situ stress determination away from mine workings on the 3080 foot level (3), and a triaxial stress measurement in the boundary pillar were carried out (4). In addition, convergence has been measured between roof and floor, and vibrating wire stressmeters have been installed in several locations to monitor stress changes in the affected area.

The objective of the present investigation was to conduct pillar stress measurements for the purpose of determining the current mining stresses at selected locations of the mine and comparing them with the estimated pillar stresses.

PILLAR STRESS MEASUREMENTS

Five accessible test locations were selected for the pillar stress measurements. The stress measurement sites are shown in Figures 1, 2 and 3. The test holes (~5° up-holes) were drilled perpendicular to the pillars in the conglomerate reefs. For strain recovery measurements, a four-gauge CSIR biaxial strain cell (doorstopper) was used. The tests provided the measurements of the two-dimensional stress field on a plane normal to the axis of the borehole. Sixteen successful overcoring tests were performed.

All test specimens were checked in the laboratory for rock-cell bond quality and gauge response. The results indicated that the loading and unloading curves were identical, as shown in the Appendix.

The elastic constants of the rock were evaluated from the results of the unaxial compression tests on BW-size intact core samples, obtained from the test holes. The results are shown in Table 1. The mean values for elastic modulus of 81.0 GPa, and for Poisson's ratio of 0.13 were used for the stress tensor calculations.

Table 1 - Determination of elastic modulus and Poisson's ratio in uniaxial compression tests.

Sample No.	Elastic Modulus (GPa)	Poisson's Ratio
D1	80.20	0.11
D2	73.45	0.14
D3	76.95	0.16
D4	85.90	0.12
D5	83.00	0.13
D6	86.70	0.14
Mean:	81.03±5.18	0.13±0.017

Note: core diameter 42 mm; height/diameter ratio: ~2.5

Test locations, setting depth and the strain recovery data are given in Table 2. Based on the elastic strain recovery by overcoring measurements, the calculated magnitudes of maximum and minimum stresses and the direction of maximum stresses on the plane perpendicular to the axes of the boreholes are given in Table 3.

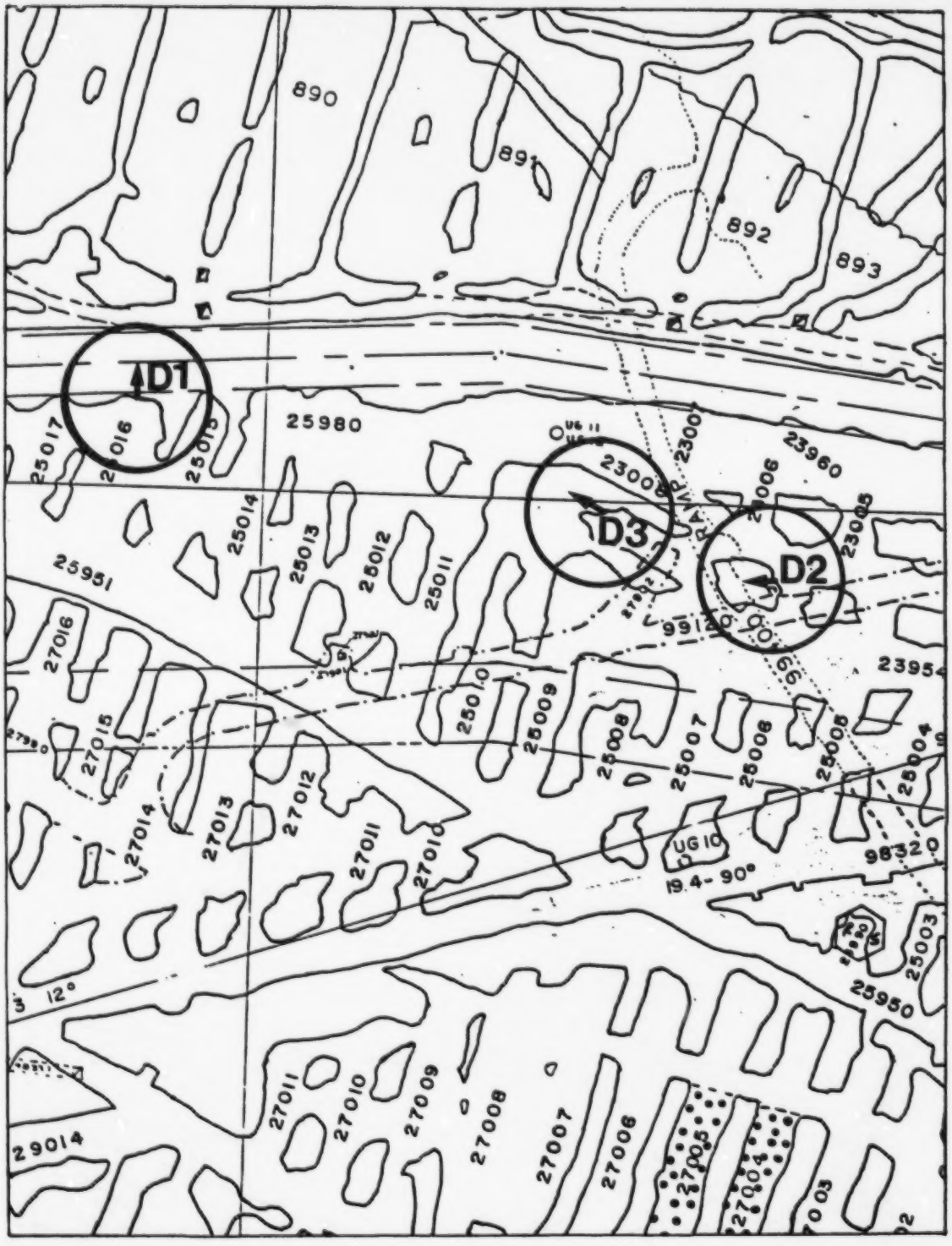

Fig. 1 - Pillar stress determination sites and test hole directions, Denison Mine (approx. scale 1:1000).

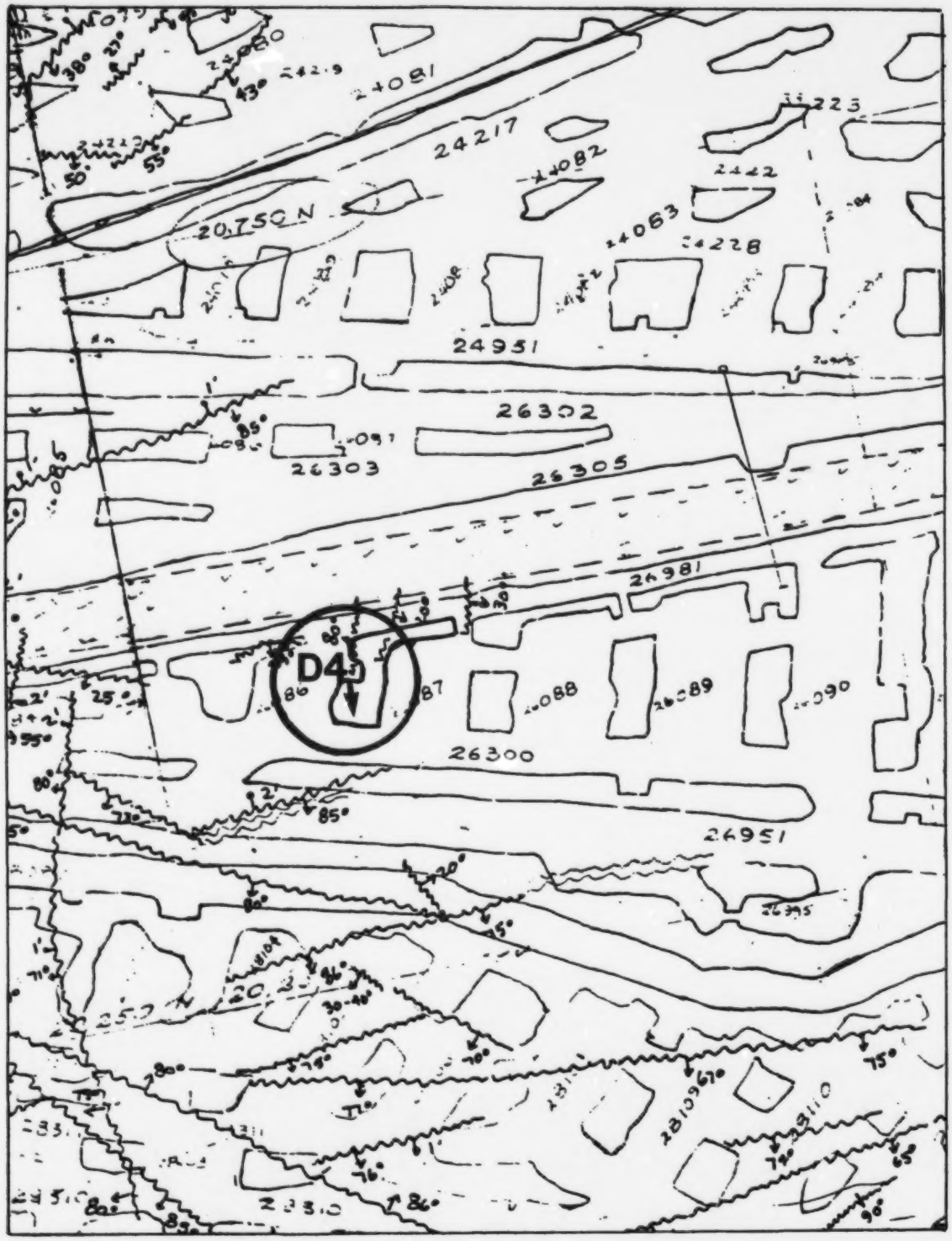

Fig. 2 - Pillar stress determination site and test hole direction, Denison Mine, (approx. scale 1:1000).

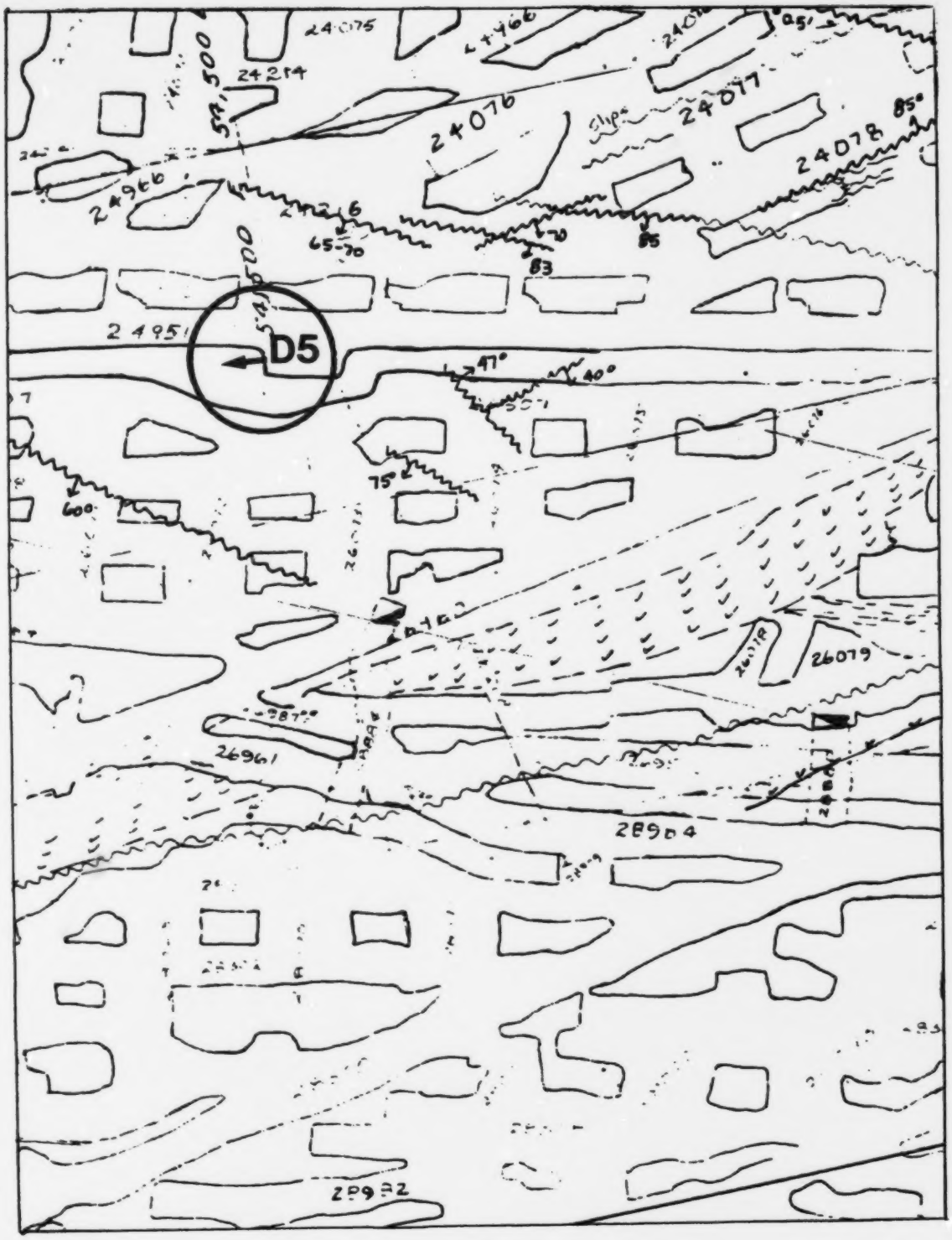

Fig. 3 - Pillar stress determination and test hole direction, Denison Mine, (approx. scale 1:1000).

Table 2 - Strain recovery from biaxial strain cell measurements, Denison Mine.

Location	Test No.	Test Depth (m)	Strain Recovery (10^{-6} in/in) Vert. S1	135° S2	Horiz. S3	45° S4	SI*
25016 stope	D1-1	3.90	424	456	372	338	2
	D1-2	4.25	282	365	375	274	21
	D1-3	4.80	264	401	324	179	8
	D1-4	6.10	280	252	360	388	0
25006 stope	D2-1	2.70	543	645	153	19	32
	D2-2x	3.00	517	1000	511	66	38
	D2-3	3.90	637	716	164	42	43
	D2-4	5.65	523	742	211	-33	25
23951 stope	D3-1	2.20	161	434	510	275	38
	D3-2	4.10	40	410	724	372	9
	D3-3x	5.10	80	531	938	348	139
	D3-4	6.40	50	503	600	100	47
26086 stope	D4-1	1.50	576	462	555	693	24
	D4-2	3.65	491	430	276	333	4
	D4-3	4.20	434	295	119	276	18
24951 stope	D5-3x	3.50	93	535	558	163	47
	Tests D5-1, D5-2, D5-4 and D5-5 were not successful.						

* Strain invariance, according to elastic theory (5): $(S_1+S_3)-(S_2+S_4)=0$

x Tests with poor bonding.

Table 3 - Pillar stress magnitude and direction from biaxial strain cell measurements. Denison Mine.

Location	Test No.	Maximum Stress (MPa)	Minimum Stress (MPa)	Direction of Max. Stress-
25016	D1-1	32.0	25.0	124
stope	D1-2	27.0	19.0	-19
(Boundary)	D1-3	27.0	14.0	-36
pillar	D1-4	28.0	18.0	-30
	Mean:	28.5±2.3	19.0±4.5	Sub-vertical
25006	D2-1	44.0	4.0	120
stope	D2-2*	64.0	12.0	134
	D2-3	49.0	5.0	118
	D2-4	48.0	3.0	129
	Mean:	47.0±2.6	4.0±1.0	Vertical
23951	D3-1	35.0	16.0	-13
stope	D3-2	47.0	10.0	-2
	D3-3*	60.0	4.0	-5
	D3-4	42.0	2.0	-17
	Mean:	41.3±6.0	9.3±7.0	Sub-horizontal
26086	D4-1	48.0	35.0	50
stope	D4-2	34.0	21.0	102
	D4-3	30.0	11.0	92
	Mean:	37.3±9.4	22.3±12.0	Vertical
24951 stope	D5-1	41.0	10.0	-20

- Angles in degrees counter-clockwise (positive) from horizontal.

* Tests rejected, according to quality checks.

DISCUSSION

It is relevant to consider the measured stresses in the context of the geometric configurations of the pillars for most values obtained. The geometric differences account partly for the variation in the magnitudes and the direction of stresses measured. Subsequently, the existence of a biaxial stress field in the test site No. 1 (25016 stope, boundary pillar) resulted in some variation from the expected maximum stress in vertical direction (normal stress). In the test site No. 3 (23951 stope), and No. 5 (24951 stope), the pillar geometry may have caused the stress concentration acting in a horizontal direction. In the test site No. 2 (25006 stope), and No. 4 (26086 stope), stresses normal to the orebody are measured.

The measured pillar stresses were compared with the method of estimating pillar stress (5), which calculates the stress normal to the orebody. As shown in Table 4, there is a good agreement between the maximum measured and the estimated pillar stresses. The discrepancy is attributed to the sensitivity of the measurements, the experimental accuracy of the overcoring tests and variation in the extraction ratios in a relatively anisotropic stress field. However, the overall stress pattern obtained from strain recovery measurements is consistent with the pillar geometry and the distribution of mine openings around the test locations.

ACKNOWLEDGEMENTS

The cooperation of Denison Mines Limited, and especially B. Mossop is appreciated. G. Vaillancourt, Elliot Lake Laboratory performed the laboratory tests and carried out part of the field measurements.

Table 4 - Comparison of measured and estimated pillar stresses, Denison Mine

Location	Measured Stress (MPa)	Estimated Stress (MPa)* Magnitude	Extraction
25016 Stope (Boundary pillar)	Range: 27.0-32.0 Mean: 28.5±2.3	37.2	62%
25006 Stope	Range: 44.0-49.0 Mean: 47.0±2.6	44.0	68%
23951 Stope	Range: 35.0-47.0 Mean: 41.4±6.0	37.0	62%
26086 Stope	Range: 30.0-48.0 Mean: 37.3±6.0	35.0	60%
24951 Stope	41.0	45.0	69%

*Estimated pillar stress (6) $\sigma p = \frac{Sv \cos^2\alpha + Sh \sin^2\alpha}{1-R}$ or,

$$\sigma p = \frac{D(0.027 \cos^2\alpha - 0.04 \sin^2\alpha)}{1-R}$$

where, σp = pillar stress.

Sv = vertical overburden stress,

Sh = horizontal pre-mining stress (1.5 x 0.027)

α = dip of orebody,

D = depth from surface (m),

R = extraction ratio.

The estimated stress is based on: D = 490 m, $\alpha = 21^{o}$, and the estimated extraction ratio in the test area.

REFERENCES

1. Steffan Robertson and Kirsten, "Numerical modelling and stability evaluation for the Denison/Quirke boundary pillars and No. 1 shaft area"; Contract Report Nos. 55801/2 for Denison Mines; June 1985.

2. Golder Associates, "Regional model studies for Quirke/Denison Mines", August 1985.

3. Hunt, G., "Three dimensional stress measurements at the 3080 foot level in 95600 drift using CSIRO triaxial cells"; Internal Report, Denison Mines Ltd.; 1984.

4. Hunt, G., personal communication.

5. Davies, D.L., "Statistical methods in research and production"; Oliver and Boyd, London, U.K., p. 396; 1967.

6. Hedley, D.G.F., "Design guidelines for multi-seam mining at Elliot Lake"; CANMET Report 78-9; CANMET, Energy, Mines and Resources Canada; 1978.

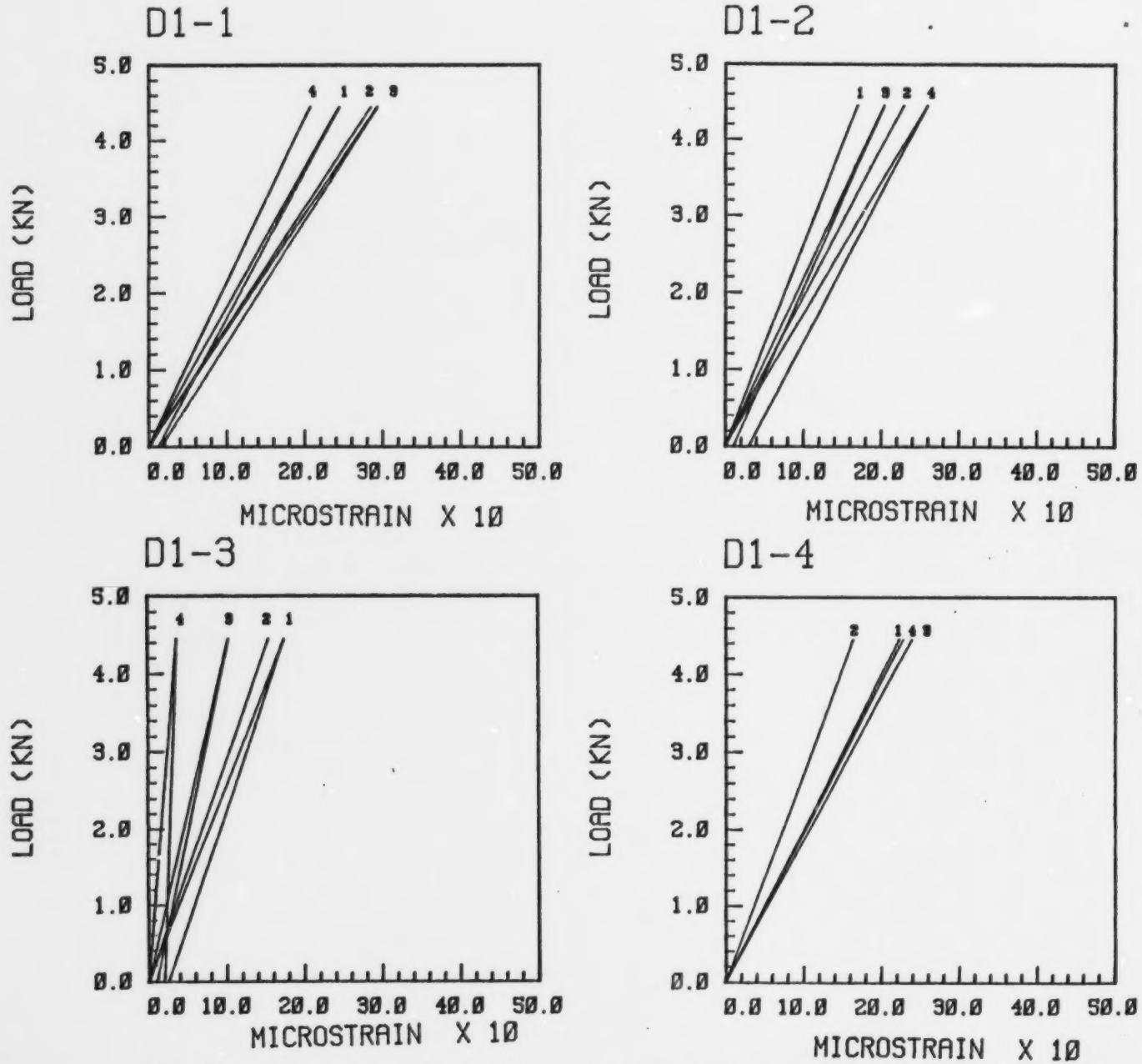

Fig. A-1 - Gauge response and linearity from loading cycle in uniaxial compression

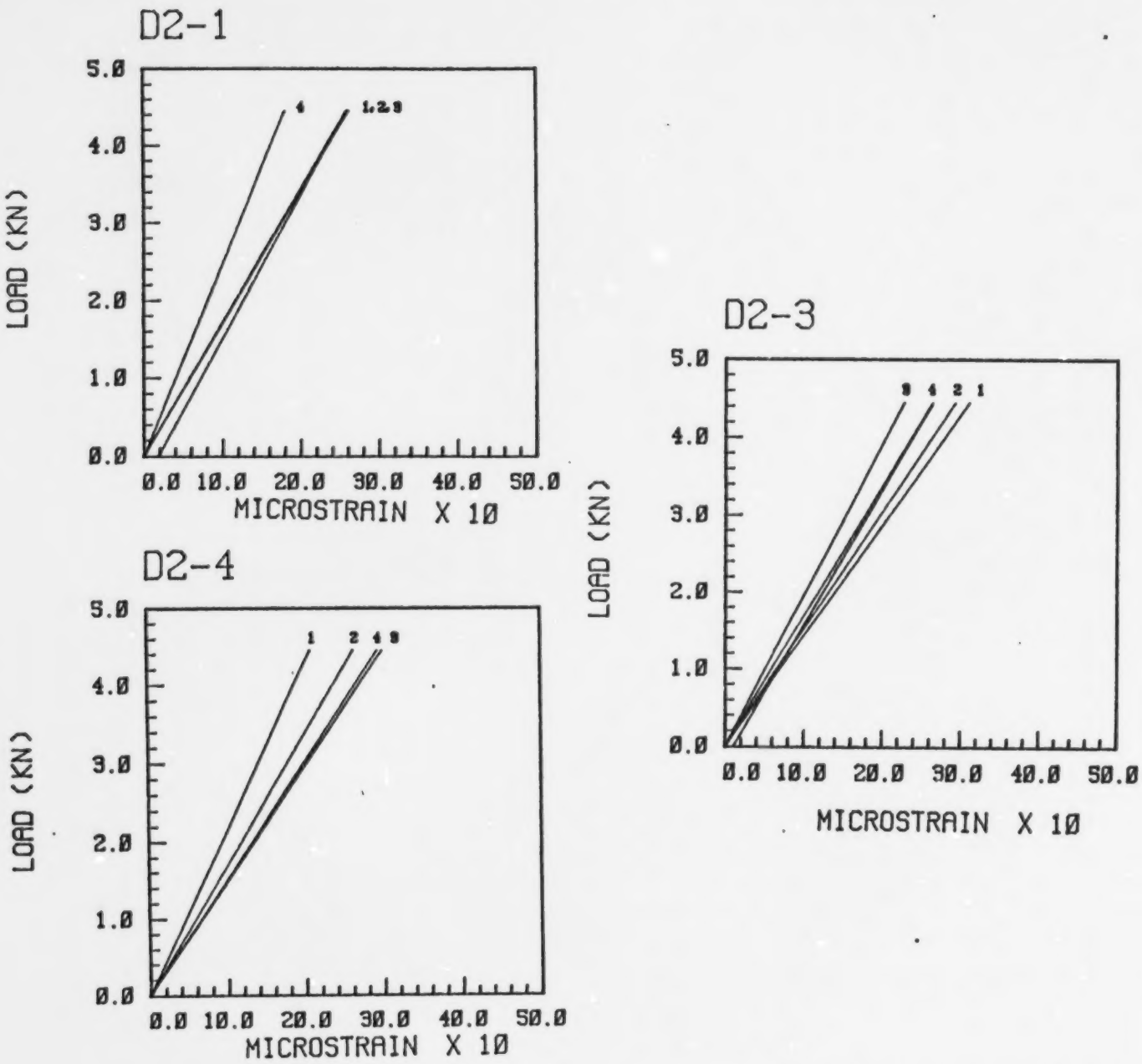

Fig. A-2 - Gauge response and linearity from loading cycle in uniaxial compression.

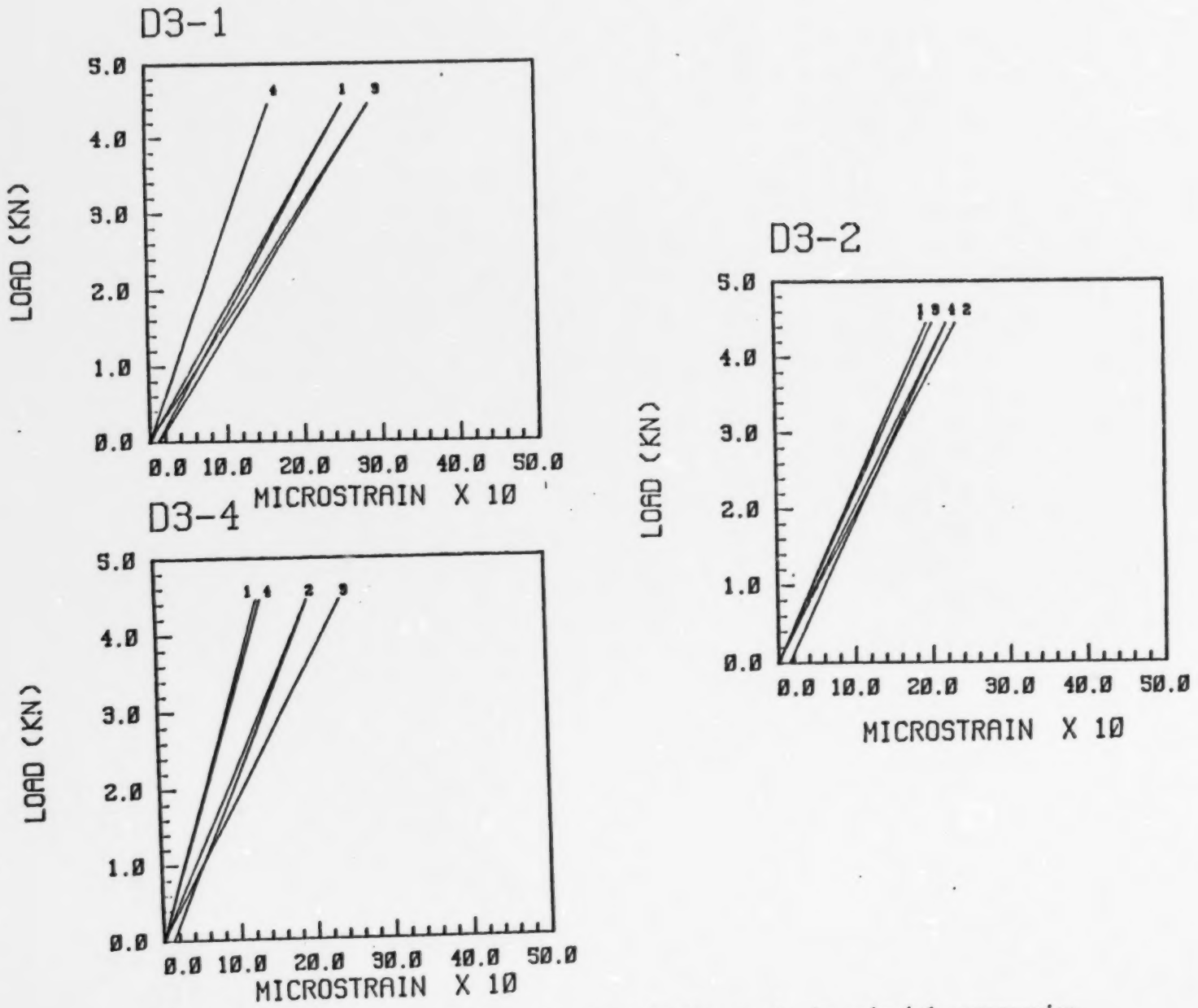

Fig. A-3 - Gauge response and linearity from loading cycle in uniaxial compression.

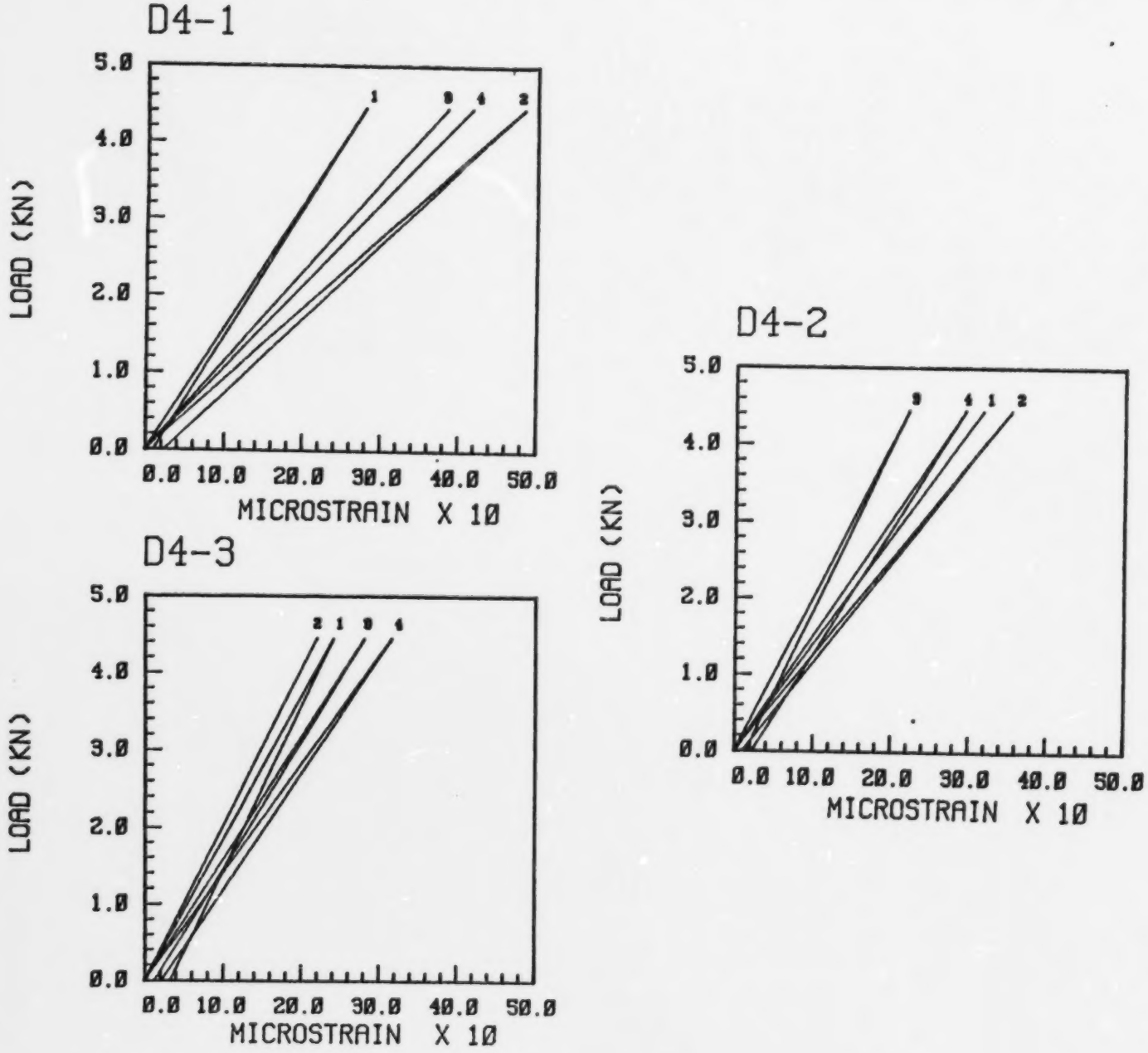

Fig. A-4 - Gauge response and linearity from loading cycle in uniaxial compression.